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THE DETERMINATION OF CARBON MONOXIDE IN MINES WITH THE "IODINE PENTOXIDE" DETECTOR

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Introduction

Carbon monoxide is often found in mines, particularly during and after mine fires and after mine explosions. This gas has the property of combining with the haemoglobin or red coloring matter in the blood and thus preventing the normal delivery of necessary oxygen to the various tissues of the body. Because of this, headaches and discomfort frequently result after 2 or 3 hours of breathing an atmosphere containing as little as 0.04 per cent of carbon monoxide, while exposure to a concentration of 0.3 per cent usually produces unconsciousness in 20 or 30 minutes -- followed by death if the victim is not promptly removed to fresh air. The gas is all the more dangerous because it is colorless, odorless, and tasteless, thus affording no warning of its presence that can be perceived by the unaided human senses.

The various methods commonly used by the Bureau of Mines for determining the presence of carbon monoxide in mine air include: Observation of the effect on small animals, particularly canary birds and mice; the pyrotannic acid method of determining carbon monoxide in blood samples; volumetric gas analysis by absorption or combustion; and the iodine pentoxide method. That canary birds or mice are more susceptible than human beings to the effects of carbon monoxide has so long been recognized as a means of detecting this gas in mines that further comment is not needed. The underground use of the pyrotannic acid method is somewhat restricted by its limitation to air containing not over 0.2 per cent of carbon monoxide. Volumetric gas-analysis methods require technical skill and training on the part of the analyst, as well as apparatus that is either too delicate or too cumbersome to be carried about underground, hence these methods are employed almost exclusively in the laboratory. The iodine pentoxide hoolamite method, however, permits the use of a carbon monoxide detector which determines the amount of carbon monoxide in mine air quickly, simply, and with reasonable accuracy. As the method is of comparatively recent origin, it is not known as well as might be advantageous to men concerned with fighting mine fires or with rescue and recovery after mine explosions. The following description of the detector used by the Bureau of Mines and discussion of its operation should therefore be of interest.

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Description of the Detector

The most essential feature of the detector is a small glass tube (Fig. 1, DN-4) containing granular pumice stone impregnated with a mixture of iodine pentoxide and fuming sulphuric acid. This mixture is called hoolamite after Hoover and Lamb, who patented the formula ($I_2O_5+H_2SO_4+SO_3$) on November 4, 1919. When air containing carbon monoxide is forced through the tube by means of a rubber aspirator bulb and suitable valves (illustrated in Fig. 1) iodine is liberated and the original white of the granules is changed to various shades of bluish green or even violet-brown or black, depending upon the amount of carbon monoxide. The chemical reaction that liberates the iodine is indicated by the formula: $I_2O_5+5CO+H_2SO_4+SO_3 = 5CO_2+I_2+H_2SO_4+SO_3$. The color imparted to the granules, unless produced by high concentrations of carbon monoxide, fades rapidly after each test, and a tube ordinarily may be used seven or eight times before its effectiveness is destroyed. Exhaustion of the material in the tube is indicated when the usual color fails to fade or has a yellowish discoloration.

The mixture of iodine pentoxide and fuming sulphuric acid deteriorates if subjected to moisture, hence the tubes are furnished by the manufacturer drawn to a tip at each end and hermetically sealed. These tips are broken off just before the tube is inserted in the instrument for use. Each tube also has a shoulder at one end which fits into a rubber connecting joint (Fig. 1, DN-24).

A second glass tube containing five shades of permanently colored pumice stone is mounted beside that containing the patented mixture. These shades correspond to colorations produced when definite amounts of air containing 0.1, 0.2, 0.3, 0.5, and 1.0 per cent of carbon monoxide, respectively, are forced through hoolamite. Thus, a quantitative determination of the amount of carbon monoxide in the mine air can be made by squeezing the aspirator bulb the number of times (usually 10) needed to furnish the amount of air for which the permanent colors are calibrated and then comparing the resulting color with those in the color scale. If such a test indicates that the amount of carbon monoxide present is not within the calibrated range a fairly accurate determination can be made by squeezing the aspirator bulb some multiple of the usual number of times and making a corresponding correction in the percentage of carbon monoxide indicated by the color tube.

Other gases and vapors, such as ethylene, gasoline, hydrogen chloride, hydrogen sulphide, and the higher hydrocarbons of natural gas, if permitted to pass through the glass tube would also cause color changes in the iodine pentoxide mixture; therefore, the detector has a nickeled cylinder (Fig.1, DN-7) containing chemically treated or "activated" charcoal which removes such undesirable gases as the air to be tested is drawn through it. The chemically treated charcoal eventually becomes saturated with these gases and requires replacement. Saturation is indicated by coloration of fresh hoolamite when pure air is forced through it. The inlet end of the nickeled cylinder has a corrugated tip to which a rubber hose may be attached. If the other end of such a hose is connected with a pipe leading through the stopping of a sealed area the percentage of carbon monoxide in the air behind the seal may be ascertained. Determinations of this sort are particularly useful during the work of fighting mine fires.

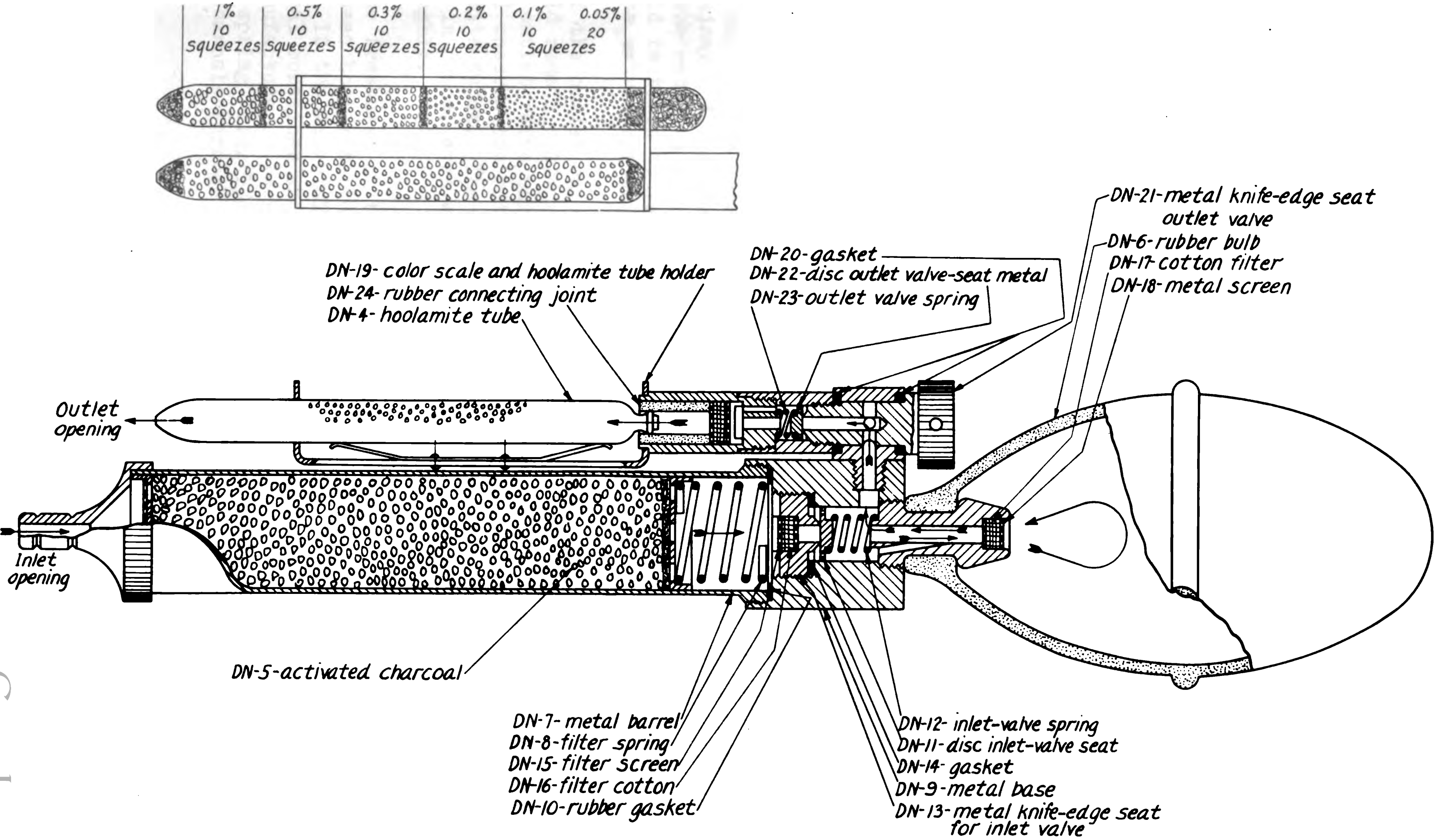

Figure 1.-"Iodine pentoxide" detector for carbon monoxide.

Inspecting the Detector Before Use

Before the detector is taken underground it should be carefully inspected to make sure that the aspirator bulb does not leak and has the proper resilience, that the valves of the instrument are tight and function properly, that the color tube is held securely in place, and that the activated charcoal is in good condition.

When the aspirator bulb (Fig. 1, DN-6) is squeezed a current of air should issue from the rubber connecting joint (Fig. 1, DN-24) into which the hoolamite tube is to be inserted; and when the bulb is released a current of air should enter the inlet opening at the end of the nickeled charcoal container (Fig. 1, DN-7). Hence, the condition of the bulb may be determined by testing it with both of these openings closed. If the bulb is sound it can not be squeezed flat; if it lacks resilience, it will not go back into shape promptly after being collapsed. A bulb that is found to be defective should be removed and replaced. The bulb may be removed by grasping the nickeled charcoal container with one hand and giving a twisting pull on the bulb with the other.

If the inlet valve is tight, no air will be lost when the aspirator bulb is squeezed as long as a finger is held tightly over the opening in the rubber connecting joint (Fig. 1, DN-24). If the valve is functioning properly and the inlet aperture is open the aspirator bulb after being collapsed will refill rapidly as soon as the hand pressure is withdrawn. The parts of an inlet valve that leaks or sticks may be made accessible for cleaning or repairing by unscrewing the charcoal container and removing the inlet valve-seat (Fig. 1, DN-11) with a screw driver. The metal valve seat can then be wiped clean with a cloth. In reassemblin care should be taken to replace the spring (Fig. 1, DN-12) in the proper position to hold the valve seat in place.

If the outlet valve is tight and the inlet aperture is closed the aspirator bulb should remain collapsed when the pressure that deflated it is released. To reach the outlet-valve parts for cleaning or repairing, remove the charcoal container and unscrew the metal holder (Fig. 1, DN-19) that carries the color scale and hoolamite tubes. The spring in this metal holder should be adjusted to hold the tubes in place, even when the instrument is grasped by the aspirator bulb and shaken roughly.

The freshness of the chemically treated charcoal may be tested by inserting an unused hoolamite tube in the instrument and squeezing the bulb 20 times in pure air. If the material in the tube becomes discolored under these conditions the charcoal container should be refilled with fresh activated charcoal supplied by the manufacturer. In reassembling the instrument, care should be taken to replace the spring (Fig. 1, DN-8) that holds the charcoal in place correctly, otherwise air channels through the charcoal might result.

Use of the Detector in Mines

Assuming that the operator is protected by a suitable gas mask or other apparatus when working in an atmosphere liable to contain carbon monoxide, he should use the detector in the mine in the following manner:

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1. Squeeze the bulb once or twice to remove any moisture and to fill the instrument with air identical with that to be tested.

2. Break both tips of a hoolamite tube and insert it firmly in the instrument with the shoulder securely seated in the rubber connecting joint.

3. Squeeze the bulb 10 times in succession, collapsing it completely each time. This will force about 350 cubic centimeters of air through the impregnated pumice. A slight amount of smoke or fume should issue from the hoolamite tube when the bulb is squeezed. Although this smoke is harmful if breathed directly, under ordinary conditions it will be so quickly diluted by the mine air that no symptoms other than coughing are likely to be noted. Observation of the smoke, however, is often advantageous as indicating the direction and velocity of the ventilating current in the mine.

4. After squeezing the bulb the full number of times, compare the resulting color (if any) with the permanent colors in the color tube and note the corresponding percentage of carbon monoxide. At low concentrations of carbon monoxide the color in the hoolamite tube fades rapidly, hence the comparison with the color tube should be made at once.

5. If no color comparable with those in the color tube results from 10 squeezes repeat the test, using some multiple of 10 and making the corresponding correction in the percentage indicated by the color obtained. For example, if a color corresponding to that for 0.1 per cent is obtained with 20 successive squeezes the amount of carbon monoxide in the air sampled is about 0.05 per cent; or, if a color corresponding to that for 1.0 per cent is obtained with 5 squeezes, approximately 2.0 per cent of carbon monoxide is indicated in the mine air. As stated, the operator should be protected by a gas mask or breathing apparatus when working in anything like a 2 per cent concentration of carbon monoxide.

6. Remove the hoolamite tube from the instrument promptly, as it should not be left in place longer than the time necessary to make the test. If the color in the tube does not fade or if a yellow discoloration appears, the tube should be discarded. As the iodine pentoxide mixture is highly acid a discarded tube should not be thrown where it can do any damage. If the tube is to be used again the tips should be covered with rubber caps to prevent deterioration of the contents through entrance of moisture.

Conclusion

One should recognize that the detector does not indicate a deficiency of oxygen in the atmosphere or the presence of such other gases as carbon dioxide and hydrogen sulphide; nor does it automatically give warning of carbon monoxide as the operator may actually be in an atmosphere containing this gas without using the instrument. Hence, in these respects, the detector is inferior to canary birds or mice. However, when in good condition and used in the manner outlined above, the detector affords a reasonably accurate quantitative means of determining, while underground, the percentage of carbon monoxide in the air, which it is impossible to do with small animals. Also, birds or mice should be returned to fresh air to revive them after being overcome by carbon monoxide, whereas use of the detector permits a rescue crew to proceed without delay, and additional tests for carbon monoxide can be made as the work progresses. Furthermore, the instrument is light, compact, and easily carried in the mine, needs little attention, and requires no special ability or skill for operation other than that of distinguishing between different shades of color. All of these advantages make the detector an extremely valuable tool for use by men in mine rescue and recovery work or by any others who must breathe air in which carbon monoxide may be found.-- Information Circular, Bureau of Mines, Department of Commerce.